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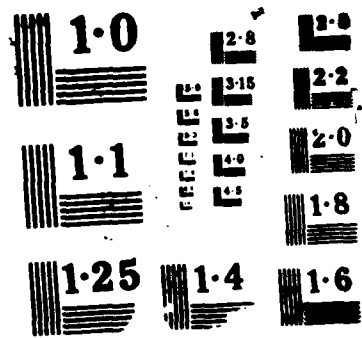
DATA MULTIPLEX SYSTEM (DMS) - ASPECTS OF FLEET  
INTRODUCTION(U) ASSOCIATION OF SCIENTISTS AND ENGINEERS  
OF THE NAVAL SEA SYSTEMS COMMAND WASHINGTON DC  
L M BLACKWELL 1987

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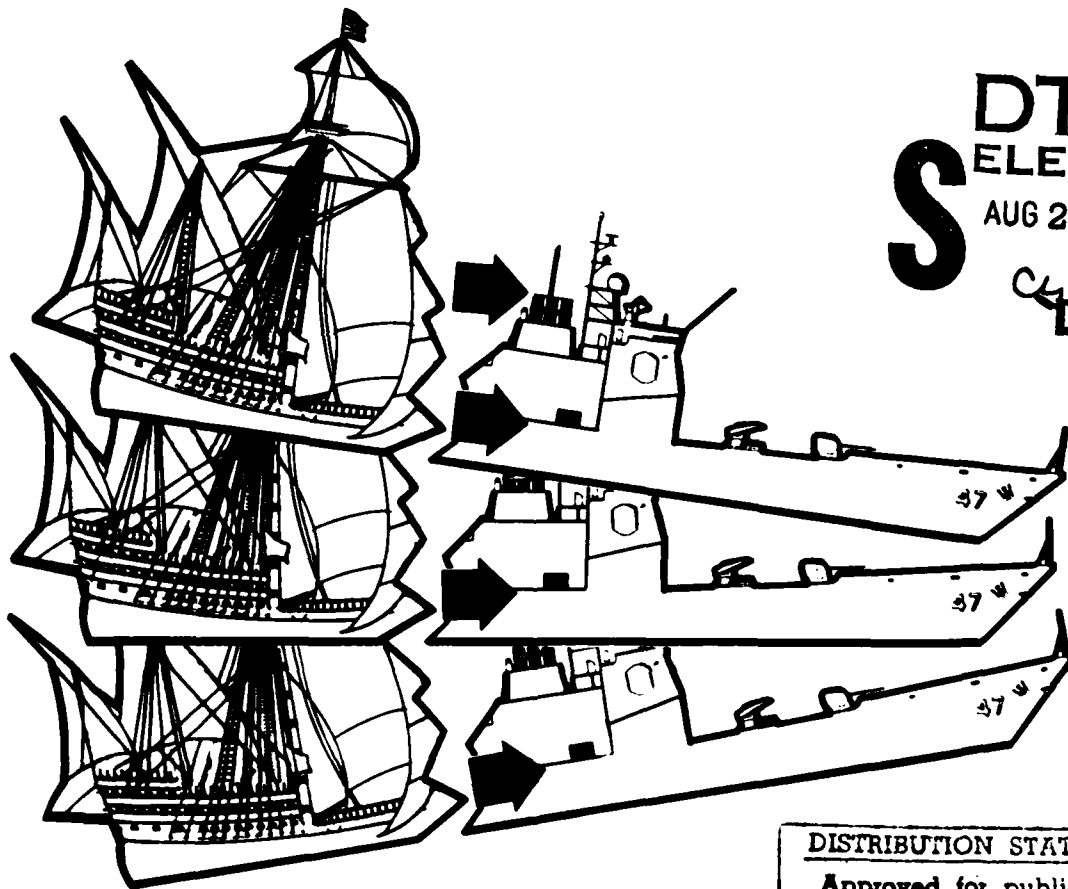


# 24TH ANNUAL TECHNICAL SYMPOSIUM

# 1987

"NAVY IN THE NINETIES — TREND AND TECHNOLOGY"

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DATA MULTIPLEX SYSTEM (DMS) — ASPECTS OF FLEET INTRODUCTION  
by: Luther M. Blackwell

Data Multiplex System (DMS)  
Aspects of Fleet Introduction

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ABSTRACT

4. DMS

The Data Multiplex System (DMS) is a general-purpose information transfer system directed toward fulfilling the internal data intercommunication requirements of a variety of naval combatant ships and submarines in the 1990-2000 time frame. The need for a modern data transfer system of the size and capability of DMS has increased as various digital control systems throughout naval ships have adopted distributed processing architectures and reconfigurable control consoles, and as the quantity of remotely sensed and controlled equipment throughout the ship has increased manyfold over what it was in past designs.

Instead of miles of unique cabling that must be specifically designed for each ship, DMS will meet information transfer needs with general-purpose multiplex cable that will be installed according to a standard plan that does not vary with changes to the ship's electronics suite. Perhaps the greatest impact of DMS will be the decoupling of ship subsystems from each other and from the ship. Standard multiplex interfaces will avoid the cost and delay of modifying subsystems to make them compatible. The ability to wire a new ship according to a standard multiplex cable plan, long before the ship subsystems are fully defined, will free both the ship and the subsystems to develop at their own pace, will allow compression of the development schedules, and will provide ships with more advanced subsystems.

This paper describes the DMS system as it is currently being introduced into the fleet by the U.S. Navy. The results of its design and implementation in the DDG-51 and LHD 1 Class ships are also presented.



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## INTRODUCTION

The Data Multiplex System AN/USQ-82(V) is currently the only approved US Navy general purpose multiplex system. The pivotal concept here is that DMS is a general purpose bus as opposed to a local area network.

A general purpose bus, simply stated, is a system which can provide compatible communications between a large quantity of different devices: computers using different digital interfaces and different protocols, analog devices, discrete, logic level, tri-level, or synchro. In comparison, a local area network typically provides communications between a small number of digital devices using a specific protocol. Thus, DMS can provide digital communications between computers using similar protocols and interfaces, as a local area network; it can provide communications between computers using different interfaces and different protocols (such as NTDS Fast to STANAG 4156); it can allow a digital computer to control or to "read" non digital devices by creating the required protocols; or it can allow two electrically compatible or electrically incompatible non-digital systems to communicate with each other.

In addition, any equipment which is connected to DMS can, if needed, be made to be accessible from any other. For example, if 10 computers and 20 indicators need to be provided with wind data, a single (or redundant) wind data transmission device connected to DMS can send these data to all of the user devices throughout the ship. Over that same digital interface, the computer devices can also access other data, control other devices, or communicate with each other. DMS can provide the data to the computer devices at certain prescribed intervals, it can allow the computers to request the data only when needed, or both. If necessary, data paths can be created, changed, or abolished instantaneously by computer users of DMS or by mechanical switches connected to DMS, operated manually.

DMS is compatible with the following interface types:

- MIL-STD-1397A Type A (NTDS Slow)
- MIL-STD-1397A Type B (NTDS Fast)

- MIL-STD-1397A Type E (Low Level Serial)
- NATO STANAG 4156 (Serial Digital NRZ)
- Discrete, Switch Closure
- Discrete, Tri-Level
- Discrete, Logic Level
- Synchro 60 Hz
- Synchro 400 Hz
- Voltage Analog ( $\pm 10v$ ,  $\pm 20v$ ,  $\pm 40v$ ,  $\pm 80v$ )

Other interfaces, such as Current Analog and RS-232, have been specified but not built to date.

Should any signal processing or data processing be required between source and sink user equipment, DMS can perform these functions by means of Message Processing Modules, which are M68000 microprocessors mounted on a standard DMS card.

DMS architecture options, a brief system description, the application of DMS to DDG-51 and LHD 1 class ships, and lessons learned are discussed in this paper. A more thorough description of DMS was given in [1], but is not necessary to understand the topics discussed herein.

#### GENERAL DESCRIPTION

In its current form, DMS is a modular, linear, coaxial multiplex system using polling cycles for channel access. A single DMS system can offer 20 simultaneous data channels shared dynamically between thousands of user devices.

The 20 channels available in a single DMS system are physically provided over 5 coaxial cables which would be located in a ship in such a way as to maximize survivability. No two channels ever carry the same data over DMS at a given time. Thus, the inherent redundancy is not "wasted". A fully operational system provides quicker service to user devices than a degraded system. However, in practical applications, a considerable amount of

degradation is required before user devices would notice any change in service. For example, in the DDG 51 application only one of the five main bus cables is needed to provide service to all DMS user devices.

Both Frequency Division Multiplexing (FDM) and Time Division Multiplexing (TDM) are used in the DMS coaxial cables. Thus, each of the 20 frequency channels available for data during any instant in time are in turn being shared, from one moment to the next, between a large number of users. It is this approach which permits thousands of users uninterrupted service over DMS.

The following is a brief functional description of the component parts of DMS. Figure 1 shows the architecture of a "dual stage" DMS. Only two main bus cables are depicted in the figure. Figure 2 shows a more compact but less flexible "single stage" DMS architecture. This approach is useful in applications which require system compactness and for which future growth is not likely to be a major consideration.

- Input-Output Unit - The IOU is a user signal conversion unit. With its variable loadout of interface cards (Input-Output Modules), the IOU converts user device signals, be they digital, discrete, analog, tri-level, logic level, or synchro, to the DMS serial digital NRZ format. Specifically excluded are RF and raw video signals. A voice interface has also not been developed. An IOU can contain up to 16 interface cards (IOMs). Each IOM can service from 1 to 16 user devices, depending on the complexity of the user interface. Up to 448 IOUs can be connected to a single DMS system.
- Remote Multiplexer - The RM is the DMS message control device. It formats and routes messages, and can be programmed to accept various protocols to accommodate a variety of computer users. Four IOUs can be controlled by a single RM. A single DMS system can contain up to 112 RMs. Each RM is internally redundant, including two complete units with separate power supplies.

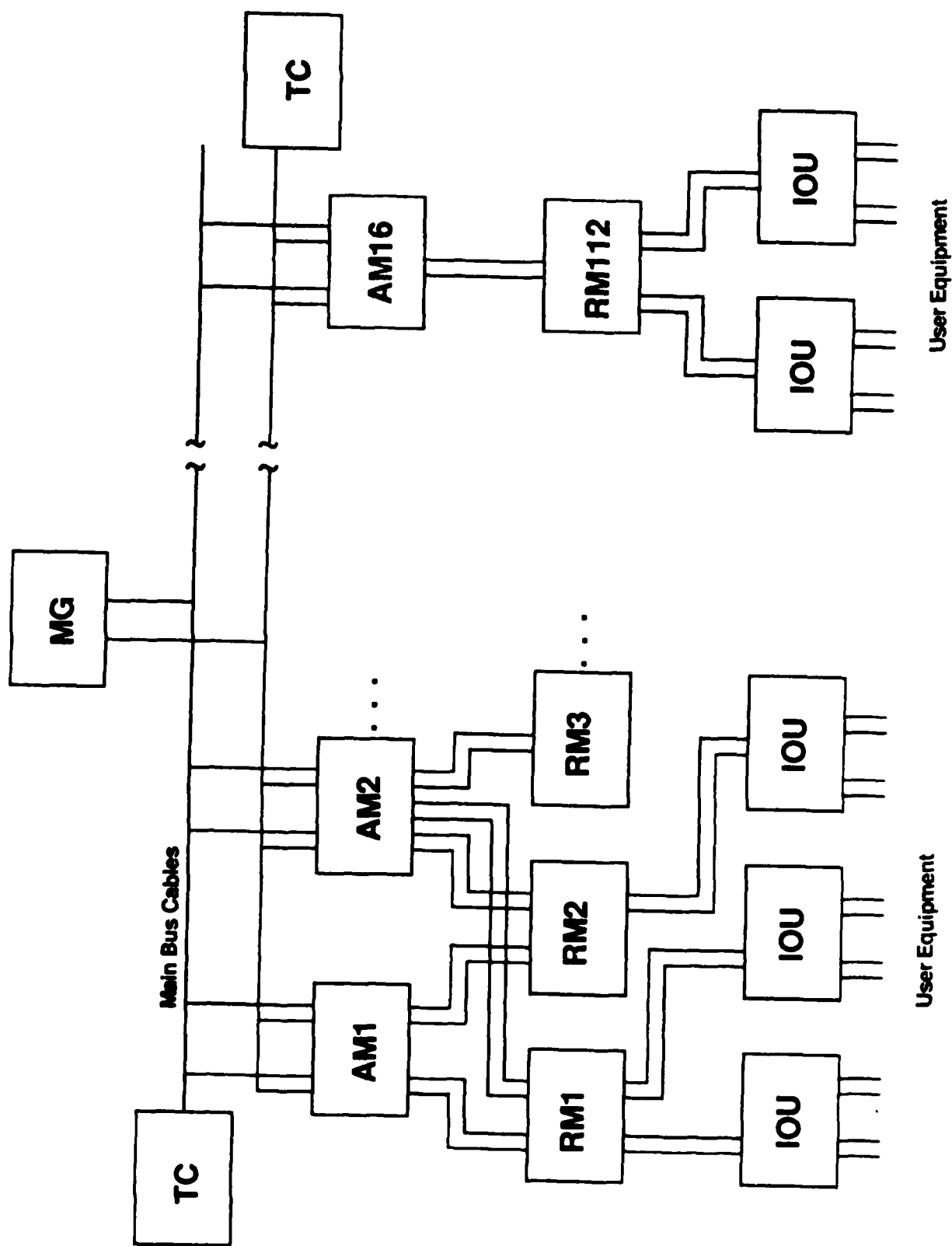


Figure 1: DMS Architecture (Partial System Shown)  
Dual Stage



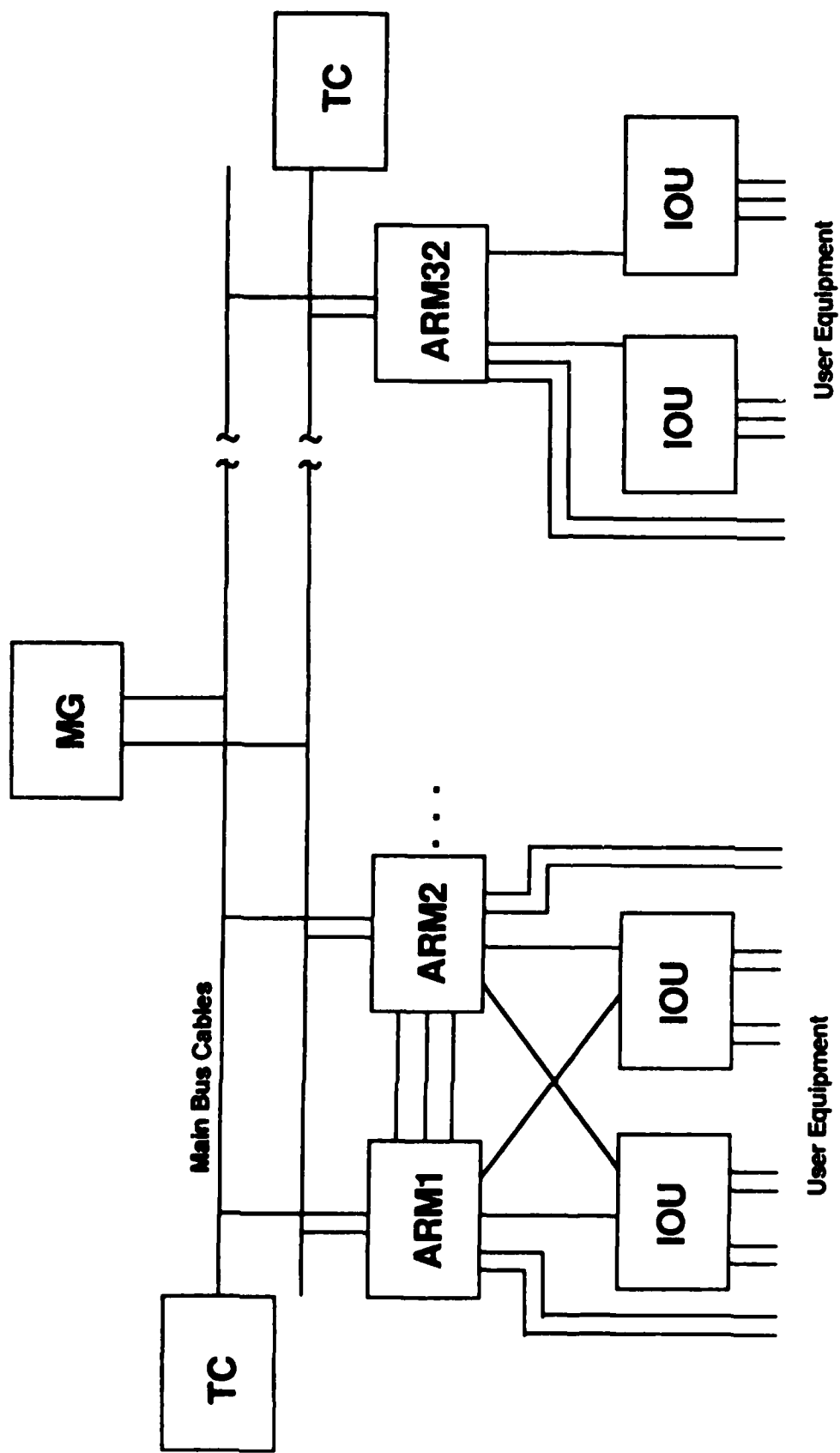


Figure 2: DMS Architecture (Partial System Shown)  
Single Stage

- **Area Multiplexer** - The AM is the unit which converts the Manchester encoded baseband digital stream from the RMs to Manchester encoded RF which is sent to the main bus coaxial cables. Each AM is completely dual redundant, as the RM. Each individual half of an RM is connected to two different AM halves. Thus, for redundancy, a single RM can be connected to up to four physically separate AMs. (On DDG 51, each RM is connected to three AMs.) A single DMS system can contain up to 16 AMs.
- **Area/Remote Multiplexers** - in smaller applications, AM and RM functions are combined in the ARM. This results in a more compact system, but does not support the same growth capability as the 2-stage AM and RM architecture.
- **Traffic Controller** - The TC is the DMS unit which monitors the data channels on the main buses. As soon as a channel is free of traffic, it offers the channel to the AMs in a prescribed sequence. One TC is connected to each main bus cable.
- **Maintenance Group** - Performance monitoring and fault localization are the functions of the MG. The MG includes a keyboard and display for man-machine interface, an AN/UYK-44 and AN/USH-26 for BITE processing, and Maintenance Electronics units to interface the processor with the DMS main bus cables. DMS operation is not dependent on the MG in any way other than as a maintenance aid.

#### DMS MESSAGE TRANSFER SEQUENCE

Unlike token passing or carrier sensing schemes, DMS is based on a concept of signal paths being established between a source and a sink selectively and asynchronously. Thus, on a periodic or a periodic basis, a source-to-sink path is established through the network. This path lasts as long as needed to send the message, and is then dissolved. The establishment of the path can either result from an internal DMS timer or from a user device initiating a request for service.

Several options are available for transferring messages through DMS. The two selected and described below are representative of the majority of message transfers in DDG 51.

- "Dumb to dumb", sink initiated. The message PROM which controls the sink device is programmed to update that device at predetermined intervals. When the timer runs out, the PROM, located in an RM close to the sink device, transmits a Receive Request addressed to the source device. The RM's Receive Request is forwarded up through an AM to the main bus as soon as a data channel is available. When the communications channel from source to sink is set up, the source RM reads the present value at the source Input-Output Module and immediately sends the data to the sink device. The data channel, source RM, and sink RM are then free for other message traffic.

The time required to obtain a data channel after the sink RM transmits its Receive Request is variable and is log-normally distributed. The typical values for a moderately loaded DMS are 200 usec on average, and 1.5 msec 99.9 percentile. The times are extended to 350 usec and 2 msec, respectively, in a heavily loaded system. However, since the data source is only queried after the channel has been established, the data senescence is only about 30 usec worst case, which is propagation time for a 3000 foot connection from source to sink added to the IOU, RM, and AM processing times.

- "Smart to smart", source initiated. When a source computer needs to communicate with a sink computer, it transmits an External Function (EF) to DMS. The EF is temporarily stored in the source Input-Output Module until it is read by the source RM. The source RM then requests a data channel to the sink device as specified by the EF. When a data channel is available, the source RM sends the request word (EF) to the sink and, if the sink computer is free at that instant, the sink RM informs the source that the sink computer is ready for data. The source computer can then transmit its data message.

The time required for the EF to be processed after it is stored in the source IOM is approximately 50 to 100 usec, depending on source RM traffic loading. As previously described, the time required for DMS to establish a communications channel with the sink device following an RM request varies typically from an average 200 usec to a worst case 1.5 msec. On the average, then, if the sink computer is free, about 300 usec are required for a computer to establish communications with another through DMS. A worst case figure in a heavily loaded system would be about 2.5 msec. Naturally, if the sink device is not free, DMS could be programmed to retry, and that time would then be extended. (These times are quite short, even by Low Level Serial user standards. In fact, computers using LLS interfaces typically need 3 to 4 msec to set up a communications link even if they are hardwired.)

#### MESSAGE TIME DELAY

The DMS gross bit rate for a data channel, once established, is 1.2 M bits/sec. Use of a parity bit and three interword gap bits reduces this to 0.96 Mbps net. This rate is independent of DMS loading, because the data channel is dedicated to the user pair once it has been established.

To estimate message delays through DMS, the example chosen is a "smart to smart" transfer in which both source and sink use NTDS Fast, 16 bit interfaces with DMS. The message length is 30 words. An NTDS Fast 32 bit interface is also used for comparison. (Note that these figures would be similar for Low Level Serial NTDS Type E interfaces.)

Since NTDS Fast transfers typically 150,000 16 bit words per second and DMS transfers 60,000 words per second, buffering is used at the input and at the output IOMs.

Once the communications channel has been established, requiring some 300 usec average DMS time as explained above, the source computer transmits its 30 word message into the IOM's data buffer. This requires 200 usec. DMS then transfers these 30 words to the output IOM's data buffer at its 60,000

word per second rate. This requires 500 usec and about 50 usec of setup time. The 30 word message is therefore available at the sink computer with a total of 750 usec of senescence added by DMS. If the word length were 32 bits instead of 16, DMS would add 1.25 msec of senescence, because DMS would send each 32-bit word through the bus as two consecutive 16-bit words.

If a particular interface type requires no buffering, such as the STANAG 4156 NRZ or the various "dumb" interfaces, the only message transfer delay is a 30 usec (worst case) propagation delay.

These buffer-caused delays are deterministic. As such, should a particular application be sensitive to them, they can often be compensated for in software.

The following table summarizes DMS-induced delays:

- Source to sink channel setup (Variable) - 0.3 msec (avg)  
2.5 msec (worst case)
- Message transfer (NTDS Fast) (Deterministic) - 0.75 msec (16 bit words)  
1.25 msec (32 bit words)
- Message transfer (unbuffered) (Deterministic) - 0.03 msec (worst case)

#### USER EQUIPMENT CONTROL OF DMS SIGNAL PATHS

The best description of DMS from a user standpoint is that it is a system of "mailboxes" or "telephone numbers." DMS users, once connected to the bus by means of IOMs, are accessible to other users provided that the appropriate address (or "telephone number") is transmitted. This feature can be invisible to a particular DMS user, or it can be capitalized on to provide the user with total control of his signal paths through the bus.

Levels of user control of DMS may be divided roughly into four categories:

1. No Control - The source and sink device are connected to each other on a periodic basis by DMS. This mode is commonly used for non-digital sources and sinks, for example an alarm sensor and a

buzzer. In cases such as this, DMS provides its own address words so as to update the user pair at a predetermined rate. A relatively small percentage of DDG 51 DMS signals are transferred in this manner.

2. Manual Control - If a small number of signal paths must be selectable, such as if a source A must communicate with a sink B, C, or D, a switch can be provided to an operator to perform this function. This switch, interfacing with a Message Processing Module within DMS, can activate and deactivate selected links through the bus by acting on predetermined message PROMs. This mode of signal control is typically used between non-digital user devices, and DMS provides the signal updates at the predetermined rates. Several such switches are used in DDG 51, and this type of message path control accounts for the majority of non-digital device message traffic in the DDG 51 DMS.
3. User Initiated Messages - In situations calling for the user device initiating the update of a particular signal, DMS can be programmed to only establish a particular path when requested. This mode is typically used between digital devices which interface with DMS in a "transparent" manner; that is, the user device is not programmed to act any differently than it would were it hardwired to the other equipment. The Inertial Navigation Sets AN/WSN-5 in DDG 51 communicate in this manner, through DMS, to the different combat system computers.
4. Full User Control - If a computer network must have full flexibility of DMS signal paths and update rates, the computers in the network can be provided with all required addresses to reach other digital or non-digital devices connected to the bus. This approach is used in DDG 51 for the Machinery Centralized Control System and the Steering Control System computer networks. When two "smart" users communicate, they format their own messages, and use DMS primarily as a communication link. When a "smart" user communicates with "dumb" users, DMS allows the "dumb" users to appear essentially as

processors to the the "smart" device; that is, DMS not only arranges the "dumb" device data in a standard digital format, but also provides all of the required protocols to permit the "smart" device to communicate with these non-digital devices in the same way and with the same I/O port that it uses to communicate with another processor. This type of communication accounts for more than half of all DDG 51 DMS signal transfers.

#### DDG 51 APPLICATION

The DMS suite designed into DDG 51 consists of the following units:

<u>DMS Unit</u>	<u>Quantity</u>
TC	5
AM	5
RM	9
IOU	29
MG	1

In addition, 293 Input-Output Modules (IOM) are housed in the 29 IOUs.

An indication of the inherent flexibility of DMS can be seen by the change in equipment quantities through the DDG 51 design phases. The "signals", or point to point communication requirements of DMS in this application, have varied from approximately 2400 to 4700 between Preliminary Design and Detail Design phases. User equipment interfaces have varied from about 1000 to 1700. (These 1700 interfaces consist of 15 different standard US Navy interface types.) DMS unit quantities have remained constant throughout. The changes have been completely absorbed by already available spare IOM channels, by adjustments in IOM quantity and mix, and by changes in message PROM coding. IOM quantities have varied from 235 during the early Contract Design phase to 306 in early Detail Design, to the current 293. The generic IOM types used are distributed as follows:

<u>IOM Type</u>	<u>Quantity</u>
Discrete Switch Closure Input and Output	54
Discrete Voltage Level Input and Output	14
Discrete Tri-Level Input and Output	120
Analog Output	1
Synchro Input and Output	66
Serial Digital NRZ (STANAG 4156)	15
Parallel Digital Input and Output (NTDS Slow)	5
Serial Digital Input and Output (NTDS Type E)	8
Message Processing Module (M 68000)	<u>10</u>
Total	293

#### DDG 51 Users of DMS

The primary users of DMS in DDG 51 can be separated into five categories: Machinery Centralized Control System (MCCS), Steering Control System, Combat System, IC Alarm and Indicating Systems, and Navigation. In terms of relative quantity of signals, these categories can be divided as follows:

<u>Category</u>	<u>Examples</u>	<u>Percentage</u>
MCCS	Propulsion, electrical, auxiliary, and damage control signals, both status and commands	76.2
IC Alarms	Dew point, air flow, intrusion, IVCS, and high pressure alarms; valve position indicators; CPS pressure; rudder angle, RPM/Pitch indicators; wind indicators	8.8
Steering Control Control	Rudder angle orders, autopilot orders and status, steering system mode commands and status, steering system pump commands and status	6.4
Navigation	Own ship head, own ship speed, roll, pitch, distance indicators	6.3
Combat System	IFF antenna bearing, digital navigation data, VLS status, DDRT data	2.3

Amplifying remarks are included on the above user categories.



## MCCS Users

Clearly the largest user of DMS, MCCS is also the system which most fully utilizes the DMS capabilities in DDG 51. The MCCS consists of six AN/UYK-44 processors, a non-digital Bridge Control Unit, and hundreds of sensors, controllers, actuators, and indicators distributed throughout the ship. All of these devices are connected together in a network which uses DMS as communications medium. Several casualty modes are built into the MCCS/DMS system to provide full redundancy of signal paths as well as degraded modes of operation. The MCCS processors communicate, over dual redundant DMS interfaces, with each other and with the non digital elements of the MCCS network. In addition, one of the MCCS processors accesses the EM Log, which is connected to DMS, to obtain own ship speed data, and a Message Processing Module within DMS is used to maintain time-of-day (GMT) for use by the MCCS processor. GMT is obtained from the Inertial Navigation Sets and is used to update a clock in the MPM. Thus, DMS is providing, with no increase in ship cabling, a bridge between MCCS and navigation systems.

The DDG 51 MCCS network is fully comparable, in terms of size, sophistication, and communications requirements, to modern digital combat systems. However, because it uses DMS, the MCCS processors need not be provided with the very large I/O port capabilities typical of combat system computers.

## Steering Control System

Similar to MCCS but on a smaller scale, the Steering Control System in DDG 51 also uses DMS to full advantage. The steering system's AN/UYK-44 processor communicates with the steering Bridge Interface Electronics Unit as well as non digital steering system equipment through DMS. As MCCS, the steering system processor also accesses the Inertial Navigation Sets for own ship head, roll, and speed data, and the EM Log for another speed source. The steering system includes numerous non-digital to non-digital communication links through DMS.

## Navigation System

The Inertial Navigation Sets (AN/WSN-5) provide numerous indicators throughout the ship with synchro data. This function is normally performed by synchro amplifiers in the IC switchboards and cabling to the indicators throughout the ship. DMS instead receives the synchro data from the inertial navigators as if it were the only user, then distributes it to the appropriate sinks throughout the ship. Some of the users of AN/WSN-5 data only need one or the other navigator as source. DMS provides these users with the appropriate source of data as a function of the AN/WSN-5 Primary and Override Select Switches. The logic necessary to determine the correct source of data and to activate the appropriate signal paths resides in a pair of redundant Message Processing Modules. EM Log signals are routed throughout the ship in a similar manner.

## Combat System

AN/WSN-5 digital signals to four of the combat system computers are provided through DMS. In accomplishing this function, DMS also allows a single NTDS Parallel Slow port at each AN/WSN-5 to communicate to four NTDS Type E (Low Level Serial) computer interfaces in the combat system. This port expansion/conversion function provided by DMS permits the AEGIS combat system in DDG 52 onward to use the same software and hardware as DDG 51.

DMS is used as alternate source of input data for the Digital Dead Reckoning Tracer (DDRT). In the normal implementation, the DDRT receives periodic updates on distance traveled from the Command and Decision System computer. Since DMS receives position data from the inertial navigators, the DDG 51 DDRT, connected through DMS, was made to receive distance traveled inputs from the C&D computer or from a Message Processing Module, within DMS, which is programmed to emulate the C&D computer.

DMS provides few other services to the combat system, such as antenna bearing signals and VLS signals, but is not used as effectively in this area as it is in machinery control. Perhaps the most significant reason for this is that AEGIS was developed without a data multiplex system in mind. Extensive use of DMS would have therefore involved changes in a system which has already been proven in the fleet. In contrast, MCCS was designed assuming that multiplexing would be available.

#### LHD 1 APPLICATION

DMS converts all user equipment signals to a serial digital stream, then back to the format desired by the sink user. It is this inherent signal conversion capability for which DMS was designed into the LHD combat system. In fact, the small LHD system is not a bus at all, and the four DMS units are collocated with the combat system equipment. The LHD DMS suite consist of the following units:

<u>DMS Unit</u>	<u>Quantity</u>
ARM	2
IOU	2

In addition, 30 Input-Output Modules are housed in the ARMs and IOUs to interface with the user equipment. The IOMs are divided into the following generic groups:

<u>IOM Type</u>	<u>Quantity</u>
Discrete Switch Closure Input	5
Synchro Input	2
Parallel Digital Input and Output (NTDS Slow)	4
Parallel Digital Input and Output (NTDS Fast)	17
Message Processing Module	<u>2</u>
Total	30

## LHD 1 Users of DMS

In contrast to the DDG 51, all LHD 1 DMS users are combat system processors. The functions of DMS in the LHD combat system can be summarized as follows:

- Distribute digital Inertial Navigation Set AN/WSN-5 data to combat system computers. This distribution involves, as it does in DDG 51, both a port expansion function and a signal conversion function (in this case, NTDS Slow to NTDS Fast). In addition, the LHD 1 DMS also provides a protocol conversion for most of the data recipients from a two-way AN/WSN-5 protocol to an output-only protocol.
- Convert from synchro to digital and send to the Tactical Data System (TDS) computer ownship head and speed, wind speed and direction, and a selected search radar antenna azimuth.
- Send to the TDS digital radar antenna azimuth data from the five radar systems.
- Convert from synchro to digital and send to the AN/TPX-42 ownship head and speed, and wind speed and direction.
- Send a periodic clock pulse, updated from the Inertial Navigation Sets' GMT, to the Identification Friend or Foe (IFF) AN/UPX-29 processor.

Thus, although the LHD DMS application is not a data bus, signal and protocol conversion capabilities, as well as the "mail box" approach to providing data to user computers is fully exploited in the small DMS suite by the LHD combat system computers.

## LESSONS LEARNED

Introducing DMS into ship designs has confirmed some concepts which had been formulated early in the DMS design, and has surfaced issues which had not been expressed previously.

- The design of subsystems can proceed more independently when interfacing through DMS. This has been proven to a large degree especially in the MCCS area. However, there have been situations in which a hardware-related change on one side of the DMS communication link (e.g. damage control fire detectors) has caused a software change on the other side. Some of these changes are inevitable but, because DMS is between the two systems, often surprise the DMS users. For example, if fire sensors are added to the ship as a result of changes to the design of the hull or of the fire sensors themselves, it is likely that the software in the processors which analyze the data from these sensors must be updated to respond to the new data.
- Updates and improvements are more easily accomplished through use of busing. Many examples of this exist. In several cases, users of DMS have asked for and received data they were not previously being provided with absolutely no change to cabling or connections on the ship. In fact, sometimes DMS firmware also did not change. One example of this is the DDG 51 steering system. Because this is a sophisticated system which includes a digital autopilot, the system needs ownship speed, head, and roll data to function properly. By providing the appropriate address words to the steering system's AN/UYSK-44 processor, these data were made available with no impact on any of the DDG 51 drawings.
- Cable savings advantages. The most advertised advantage of using DMS has always been the savings of cable in terms of substantial weight and volume reductions. This is certainly an advantage (currently estimated at 150,000 feet and 40 tons of cable, data converters, and switchboards in DDG 51), but during the latter design phases this advantage tends to be forgotten. However, the relative ease with which distributed processing control systems can be implemented using DMS becomes a much more obvious advantage. Between Preliminary Design and Detail Design, the steering and machinery control systems were subjected to very substantial changes. Yet, because these systems interface through DMS, the impact on shipboard cabling

(routing and connections) has been relatively trivial. This has permitted designers of these systems to change their designs late in the ship design cycle with much less resistance than they would have experienced were their systems hardwired.

- Documentation. In DDG 51 DMS provides such a large amount of non-digital to digital signal conversion that it has a substantial impact on the development of much of the "smart" users' software. The documentation which formalizes the digital message formats produced by DMS was created well into the Detail Design phase. This documentation is significant enough that it should be provided earlier and that it should be contractually binding, that is, treated as are Interface Design Specifications.
- Spare capacity provided in the initial design. Large amounts of spare capacity may seem wasteful, but a system such as DMS, which is impacted on by so many other ship systems, must be provided with generous, growth capability. In the original design, at least 50 to 75 percent spare capacity should be factored into the system. There are so many uncertainties in the details of individual system interfaces during Preliminary Design, so many guesses as to what will really be the interface types, that spare capacity can easily disappear. One example that made this very clear was the Bridge Control Unit of the MCCA. This unit, in the DDG 51 Preliminary Design phase, had been identified as a "smart" device with dual redundant, digital interfaces with DMS. Overnight, during the early Detail Design phase, these two interfaces were changed to more than 200. The change was caused by the BCU design change to non-digital technology. Because DMS is the communication medium, however, no hardware impacts resulted to any other MCCA component.

#### SUMMARY

The DDG 51 and, to a smaller degree, the LHD 1 applications of DMS have made it very clear that naval ships designed now and in the foreseeable future need the features provided by a general purpose data multiplex system. The

advantage of busing which has most frequently been expressed is the saving of cable. This is undoubtedly a clear benefit. Another obvious benefit is the facilitation of system upgrades achieved because new cable runs are minimized if the added or modified equipment is interfaced with DMS. However, an even more pressing need is to facilitate the implementation of control systems using truly distributed processing. Most current US Navy distributed control systems use point to point cabling between processors and to data conversion units. This approach is severely limiting the benefits which can be accrued from these advanced architectures, which include flexibility in design, high reliability and survivability, and ease of system upgrade. As naval systems become more advanced, these "advantages" are quickly becoming absolute necessities.

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